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TRADE-OFFS BETWEEN FEMALE FOOD ACQUISITION AND CHILD CARE AMONG HIWI AND ACHE FORAGERS

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Even though female food acquisition is an area of considerable interest in hunter-gatherer research, the ecological determinants of women's economic decisions in these populations are still poorly understood. The literature on female foraging behavior indicates that there is considerable variation within and across foraging societies in the amount of time that women spend foraging and in the amount and types of food that they acquire. It is possible that this heterogeneity reflects variation in the trade-offs between time spent in food acquisition and child care activities that women face in different groups of hunter-gatherers. In this paper we discuss the fitness trade-offs between food acquisition and child care that Hiwi and Ache women foragers might face. Multiple regression analyses show that in both populations the daily food acquisition of a woman's spouse is negatively related to female foraging effort. In addition, nursing mothers spend less time foraging and acquire less food than do nonnursing women. As the number of dependents that a woman has increases, however, women also increase foraging time and the amount of food they acquire. Some interesting exceptions to these general trends

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are as follows: (a) differences in foraging effort between nursing and nonnursing women are less pronounced when fruits and roots are in season than in other seasons of the year; (b) foraging return rates decrease for Ache women as their numbers of dependents increase; and (c) among Ache women, the positive effect of number of dependents on foraging behavior is less pronounced when fruits are in season than at other times of the year. Lastly, in the Hiwi sample we found that postreproductive women work considerably harder than women of reproductive age in the root season but not in other seasons of the year. We discuss how ecological variation in constraints, the number of health insults to children that Hiwi and Ache mothers can avoid, and the fitness benefits they can gain from spending time in food acquisition and child care might account for differences and similarities in the foraging behaviors of subgroups of Hiwi and Ache mothers across different seasons of the year. Valid tests of the explanations we propose will require considerable effort to measure the relationship between maternal food acquisition, child care, and adverse health outcomes in offspring.

KEY WORDS: Hunter-gatherers; Female Food Acquisition; Ache (Paraguay); Hiwi (Venezuela); Child care; Foraging strategies; Division of labor.

This paper is dedicated to Nutsiya, the hardest-working grandmother we ever observed

The causes and consequences of female food acquisition patterns are of considerable interest in research on behavioral adaptations in hunter-gatherers (Bentley 1985; Blurton-Jones 1992; Blurton-Jones and Sibly 1978; Ellison et al. 1986; Hawkes et al. 1989; Hill 1988; Lee 1969; Peacock 1986). As in most primates, female foragers spend a considerable amount of time and energy in the care of offspring and in food acquisition activities (Altmann 1980; Lee 1979; Levine 1977; Mechan 1982; Shostak 1981). Throughout their adult lives, women face the problem of how to provide high-quality child care without greatly sacrificing efficiency in economic activities and vice versa. This problem exists because women have limited time and energy, child care and food acquisition are both potentially fitness-enhancing, and the two activities are always to some extent mutually exclusive (Hurtado 1985; Kaplan 1987; Kaplan and Dove 1987). Anthropologists are interested in the implications of these competing reproductive and economic roles for understanding the evolution of sex differences in parental investment behaviors, or the division of labor by sex (Hill and Kaplan 1988; Kaplan 1987; see reviews in Ember 1981; Rosenblatt and Cunningham 1976). Within the context of this larger question, investigators have begun to study the adaptive function of female food acquisition behaviors in foraging societies (see review in Hames 1992).

Based on the general premise that competent direct care of offspring is a key component of female fitness in humans, it has been hypothesized that women, as the primary caretakers of children under most conditions, should favor subsistence activities that do not jeopardize the effectiveness of this care (Hurtado et al. 1992). A corollary of this proposition is that women should tend to specialize in activities that appear to expose children to fewer hazards than other activities (e.g., gathering vs. hunting; Brown 1970; Burton and White 1984; Burton et al. 1977). A second corollary is that during periods of pregnancy and lactation women should spend fewer hours foraging per day than at other times when they are less encumbered by the care of offspring (Hames 1992; Hurtado 1985; Hurtado et al. 1985; Peacock 1985) because children are more vulnerable to poor health outcomes during early developmental stages than in later years. The same researchers have also proposed that women should increase foraging time as their number of children increases because older offspring are likely to benefit more from increases in maternal food provisioning than from intensive maternal care.

Interestingly, findings are sometimes inconsistent with these general expectations, and even when they are consistent (Peacock 1985), behavioral variation across seasons and groups suggests that reproductive status alone can only partially predict female time use. In fact, the intra- and intercultural variation in time allocation to subsistence among women foragers appears to be importantly patterned by the mediating effects of microecological factors (seasonality and group differences) on the relationship between reproductive status and female foraging time. In contrast to generally accepted expectations, women of all reproductive statuses are reported to hunt large game regularly among the Agta (Goodman et al. 1985). Surprisingly, female hunting behaviors do not appear to increase infant mortality rates in this group. At the same time, even though nursing women tend to work shorter hours than nonnursing women in most groups of foragers (see Hurtado 1985 for review), foraging time can differ substantially across seasons and groups when women of similar reproductive status (e.g., nursing) are compared. For example, time spent foraging among Hiwi nursing women can range between an average of 2.2 hours per woman-day in the root-gathering season and 1.4 hours per day in other seasons of the year (see below). Ache nonnursing women spend fewer hours foraging per day (2 hours, see below) than do Hadza nonnursing women (4.8 hours per day; Hawkes et al. 1987).

One useful tool for modeling complex causal pathways between ecology, fitness, and behavioral choice is an optimization model that includes consideration of constraints (Hurtado et al. 1992). Anthropologists have developed versions of these models for explaining the

variation in time spent foraging within and across groups of hunter-gatherers (Hawkes et al. 1985; Smith 1987). The most important conclusion drawn from this theoretical work is that the ecological causes of time allocation decisions cannot be adequately modeled without data on the long-term fitness benefits of spending time on alternative activities. These measurements can be obtained in large populations using epidemiological research designs (Hurtado et al. 1992). Until the necessary studies are completed, however, mathematical modeling is relatively uninformative about the qualitative or quantitative differences in behavior that we might expect to find between groups, or between individual women foragers (Smith 1987:80).

These methodological obstacles should not belittle the importance of further descriptive analyses of data on women foragers. In fact, unbiased and accurate descriptive work is a very important source of information for model building (Stephens and Krebs 1987). For example, natural controls can be introduced by collecting prospective data among the same individual women whose exposures and behaviors vary through time and across habitats. In studies of female foraging behavior, these data collection methods allow us to isolate important effects of ecology and reproductive status on food acquisition strategies. We have used this kind of research design to study differences and similarities in the foraging behaviors of Hiwi and Ache women. Reproductive states of interest include nursing vs. nonnursing, postreproductive vs. reproductive age, and the number of children that a woman has. Microecologies of interest include season of the year and ethnic group (at the population level) and the amount of food that a woman's husband acquires (at the level of the nuclear family).

THE STUDY POPULATIONS

Various aspects of the behavioral ecology of Hiwi and Ache foragers have been the subject of numerous publications (see Hill and Hurtado 1989 for review; also see Hurtado and Hill 1990, 1991). In this section we describe socioecological factors that may place constraints on women's foraging behaviors. Table 1 summarizes some contrasting features that characterize the ecologies of these two groups.

Hiwi Foragers

The Hiwi live in the savannas, or llanos, of western Venezuela. The llanos flood annually and are characterized by extensive grasslands with belts of gallery forests one to two kilometers in width. The ecological consequence of seasonal flooding is a marked fluctuation in the tempo-

Table 1. The Comparative Ecology of Hiwi and Ache Foragers

	Hiwi	Ache
Habitat		
Savanna	Forest	
Food resources	patchily distributed	evenly distributed
Clear areas		Dense underbrush
Seasonal Variance in Food Supply		
High	Carbohydrate highly variable	Low
	Animal protein stable year-round	Carbohydrate and animal protein stable year-round
Settlement Pattern		
Central place		Mobile
Camp moves	occur every 20 years	Almost daily camp moves
Temporary foraging camps	frequent in the dry season	
Foraging Parties		
Groups of women	(tuber season)	Groups of women (year-round)
Solitary males	(year-round)	
Husband-wife team	(year-round)	Husband-wife team (rare)
Groups of men	(year-round)	Groups of men (year-round)
Transportation to Foraging Sites		
Canoes	(year-round)	Walking (year-round)
Walking	(women; tuber season)	
Social Environment and Demography		
Little outside influence		Agricultural settlement with strong missionary presence
Zero population growth		Growing population
All age groups well represented	(contact ca. 1959)	Few men and women over age 45 because of contact-related deaths (contact ca. 1970)
High sterility rates		Extremely low sterility rates
Sources		
	Hurtado and Hill 1986, 1990	see review in Hurtado and Hill 1989
	Lyles et al. 1990	

ral and spatial distribution, and in the biomass and productivity, of plants and animals. Close to 90% of the precipitation falls during the months of May through November, followed by an intervening period of severe moisture stress between January and March. In contrast, temperatures are relatively constant throughout the year (Hurtado and Hill 1990). This seasonal variation is associated with long periods of

nutritional stress and may be partially responsible for low fertility and high child mortality among Hiwi foragers (Hurtado and Hill 1990).

The uneven spatial and temporal distribution of forested areas and rainfall in the Venezuelan llanos has important implications for Hiwi women's foraging strategies. The food resources that Hiwi women exploit are usually found in clumps that are far apart. Tubers, fruits, and legumes, the main food staples that Hiwi women gather, are found in discrete patches along the edges of gallery forests, in highly swampy areas in the middle of the savannas, or in the gallery forest. Carbohydrate-rich resources are rare throughout half the year.

The scarcity of carbohydrate foods in the Venezuelan llanos is attenuated by the relative safety of the llanos, especially from the point of view of parents raising small children. During the dry season the savanna is dry and cool and almost entirely pest-free, which makes traveling less difficult for women with infants and children. This feature of the Hiwi environment, in combination with central place foraging and the use of hammocks at the central place, makes camps an extremely safe area for infants and children.

The Hiwi are generally monogamous for life, with a few cases of very stable polygynous marriages (Hurtado and Hill 1991). In addition, spouses spend considerable amounts of time foraging together. Hiwi women forage with their husbands regularly in both the root season (19% of the time; 33 out of 174 foraging expeditions) and during the rest of the year (56% of 314 foraging expeditions; see below for definitions of seasons). When women forage with their spouses, they do so primarily when canoe travel is involved. They row, steer, and help men to spot game along river banks. The men help the women to gather primarily in the dry season when large loads (e.g., mangoes) are involved and the Hiwi must walk very long distances. During the tuber season, Hiwi men help their spouses by caring for children while their wives forage (see below).

In the Hiwi population, all age groups are well represented, including women of postreproductive age. Consequently, most Hiwi women in their reproductive years have older female relatives that are helpful with child care or food acquisition.

Ache Foragers

The Ache population we studied lives in the neotropical forests of eastern Paraguay. Since the 1970s, this population has become increasingly sedentary. We studied female foraging behaviors by joining small bands of Ache who left their agricultural settlement for weeks at a time to subsist as full-time foragers in the surrounding forest. Seasons are

primarily marked by changes in temperature that can reach below freezing in the months of July and August (Hill et al. 1984). This seasonal fluctuation in temperature results in small changes in the macronutrient and caloric composition of the Ache diet across the year. Unlike the llanos, the Paraguayan forest provides abundant foraging grounds with relatively evenly dispersed animal and vegetable foods. The regular source of wild foods may be partially responsible for the high fertility and child survivorship rates among the Ache relative to the Hiwi.

The benefits of a plentiful environment are offset by the dangers of the subtropical forest. Throughout the year, Ache mothers have to worry about biting ants; stinging bees and wasps; poisonous caterpillars, snakes, and spiders; and superabundant mosquitoes, gnats, and ticks that find excellent hiding places in fallen leaves, thick underbrush, and tree branches. Plant life, in turn, is full of hazards, such as thorns and stinging nettles. In addition, the forest floor is generally damp and cold during half the year; as a result, women avoid setting down infants and children even in areas that are clear of underbrush. These features of the Ache environment, in combination with the use of very small temporary camps and the fact that the Ache sleep on the ground, make the forest a very unsafe area for unsupervised infants and children year-round.

Since the mid-1970s, the age-sex composition of the Ache population has been dramatically affected by high rates of contact-related death among older individuals. Women of postreproductive age are therefore poorly represented. The majority of the Ache women of reproductive age in our sample did not reside near any older female relative. The age composition of the foraging population has been affected in yet another way. Ache children prefer, or are actively encouraged by missionaries, to attend school at the agricultural settlement rather than to accompany their parents on foraging trips. Consequently, the women in our sample generally did not have adolescent children to help them with the care of the children and foraging. The data we report here were collected on foraging expeditions of 5 to 15 days out from the agricultural settlement.

Unlike among the Hiwi, marriages tend to be unstable among Ache foragers (Hill and Hurtado 1992), and spouses rarely spend time foraging together during the day. In our sample, Ache women only foraged with their husbands in 1% of all women-days (5 out of 461 foraging days).

Women spend most of their daylight hours in the company of other women, walking in single file along a narrow trail from an old to a new camp. When they forage they disperse within close range of each other and intensively exploit palm trees for their starch, heart, or grubs. At fruiting trees, women forage within sight of each other. Even though women spend much of their time together, only very infrequently do they leave their children in the care of other adult females.

Table 2. Number of Person-days for Which Data were Collected on Calories Acquired per Day, per Hour, and Hours Spent Foraging per Day in the Hiwi Sample

Season	Month Year	Reproductive Status		
		Nursing	Nonnursing	Postreproductive
Root	November 1985	123	34	166
	December 1987	42	22	44
Other	January 1988	66	30	107
	February 1988	81	41	123
	March 1988	15	15	24
	April 1988	78	20	113
	May 1988	36	21	57
	July 1987/1988	14	9	14
Total		455	192	648
Number of individuals represented by each reproductive status		12	9	11

METHODS

Data Collection

The behavior of Hiwi women was sampled at two different sites in 1985-1986 and in 1987-1988. Table 2 summarizes the distribution of person-days sampled among women of different reproductive status, according to the month and year when the observations were made. The sample of Ache women (461 woman-days) and the methods used to measure time allocation and food acquired are described elsewhere (Hurtado 1985; Hurtado et al. 1985).

Independent Variables

Reproductive status categories were defined in the following way for both the Hiwi and Ache populations. *Nursing women* are females who were observed nursing their youngest child on sample days (36% and

55% of all woman-days in the Hiwi and Ache samples, respectively) and *nonnursing women* are females of reproductive age who were not pregnant or nursing (25% and 45% in the Hiwi and Ache samples, respectively). Figure 1 shows that the age distribution of nursing infants and children in the Hiwi and Ache samples differs slightly.

Postreproductive women are females who are at least 45 years of age and who had not experienced a live birth within 5 years of the study (39% of all woman-days in the Hiwi sample). In the Ache sample, we did not observe postreproductive women. Pregnant women were excluded from the analyses because of small sample sizes in both the Hiwi and Ache populations.

Dependent children/grandchildren are all of a woman's children and grandchildren who were in camp on the day the woman under study went foraging. This variable is designed to examine the effects of weaned status of children on maternal foraging effort. It is our impression that even though older nursing children suckle infrequently and eat lots of food (unpublished data), the kind of maternal attention that these youngsters receive is very different from that given to weaned individuals of equivalent age. Data analyses are consistent with these observations since nursing status per se is a more important and consistent

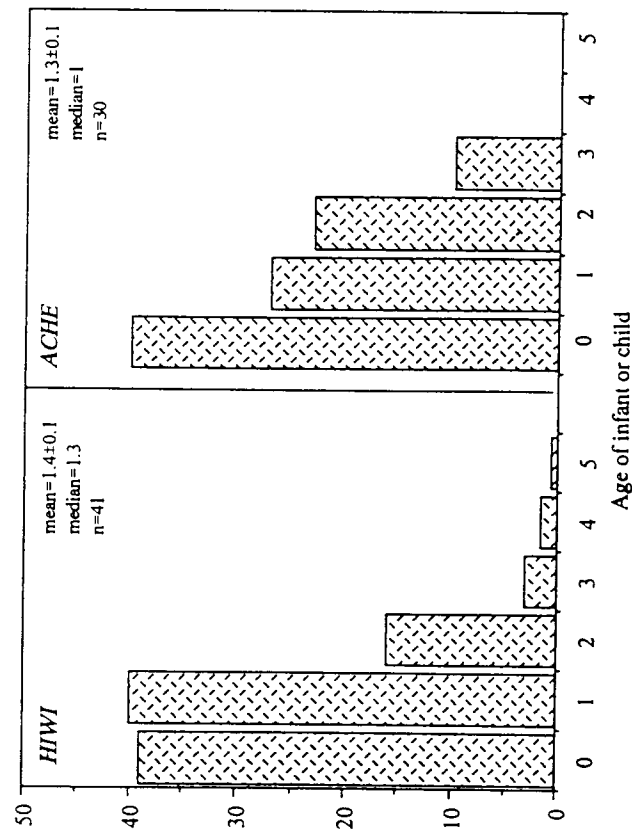


Figure 1. Age distribution of nursing infants and children in the Hiwi and Ache samples.

predictor of female foraging behavior than is age of youngest child (see below).

Number of dependent children/grandchildren includes all children and grandchildren, even those who are adults. We felt that even though men coded as dependents in the Hiwi sample of postreproductive women probably acquire more food than they consume, they still depend on maternal kin for carbohydrate foods, particularly in the root season. Adolescent males and females acquire fewer calories than they consume among the Ache (Hill and Kaplan 1988) and among the Hiwi as well (unpublished data; see also Kaplan 1991).

Husband's food acquisition was measured in both populations as the mean daily caloric acquisition in a given season or a foraging trip. We use seasonal and trip means in order to minimize the effects of high fluctuation across weeks or months caused by factors we did not measure (e.g., illness) and thus are unable to control for in statistical analyses of the data.

The effects of seasonality on women's foraging behaviors were also examined. Because we are interested in the implications of differences in harvesting methods for the costs of female foraging, the seasons were divided into "root" and "other" in the Hiwi sample. In the root season, Hiwi women dig tubers, whereas in other seasons they mainly gather wild foods (Hurtado and Hill 1990). Root digging and food gathering are costly activities for Hiwi women. Roots have to be dug out with metal or wooden digging sticks, which requires considerable physical effort. Food gathering involves having to carry infants, small children, and heavy loads over long distances.

Ache women gather fruits ("fruit trips") on some trips and on others they mainly extract palm starch ("palm starch trips"). Among the Ache, fruit collecting requires little effort or attention and is easily undertaken while an infant is being held or while older children are kept within the view of the mother. On the other hand, palm starch exploitation seems to require as much effort as does root extraction. It involves chopping down trees, peeling the bark from the tree, and pounding the pith with an ax. In addition, women are usually unable to watch their small children while they gather this resource.

Dependent Variables

Time allocation was measured as the number of hours per woman-day spent searching and in pursuit of food resources (*foraging time*). In the Hiwi population, women were clocked from the time they left the residential camp to forage until the time they returned to camp. Among the Ache, women were clocked from the time they left the overnight

camp, or a rest camp during the day, until the time they returned to camp (Hurtado 1985; Hurtado et al. 1985). Foraging time includes both search and pursuit time: walk time between camp moves and walk time to and from the foraging patch.

Another dimension of women's time allocation is *food acquisition rate*, which is defined as the intensity with which women forage and is measured as the number of calories that are acquired per hour spent in search and pursuit time for different women foraging for the same resource in the same patch. The number of calories acquired per hour is a measure of individual differences in the intensity with which women gather foods on any one foraging day or of differences in foraging skill. For example, if four women collect fruit for 2 hours, some of them may work harder than others and thus produce more food. Finally, in the Hiwi sample the food benefits that women gain from spending time foraging were measured as the number of calories acquired per woman-day (*daily food acquisition*).

For the data on Ache women's overall food acquisition rates and foraging time we only include observations of palm starch acquisition rates and time spent in the acquisition of palm starch; these behaviors were consistently and more accurately monitored across all foraging trips than was the case for other resources. Palm starch is the main carbohydrate food staple in the Ache data. The Ache consume this resource in large quantities in all seasons of the year, and it accounts for 80% of all the calories that Ache women acquired on the foraging trips we observed (Hurtado 1985). Consequently, even though our data exclude some information on female subsistence work, they are still reliable indicators of the most important food acquisition behavior among Ache women. On the other hand, Ache *daily* food acquisition was estimated from data on all foods acquired, because all vegetable resources and their acquirers were systematically measured and noted throughout the day on all foraging trips.

RESULTS

Figure 2 summarizes trends in time spent foraging, acquisition rates, and daily food acquisition rates as a function of reproductive status and seasonality among Hiwi and Ache foragers. Interestingly, both Ache and Hiwi women spent fewer than 3 hours per day foraging in all seasons and across all reproductive states. In contrast, substantial differences are apparent in acquisition rates and daily food acquisition. The rates and daily food acquisition for Hiwi women range between 0.5 and 1.1 kcal/hr and between 0.4 and 2.7 kcal/day (see Figure 2 for means). Ache women, on the other hand, acquired substantially more food

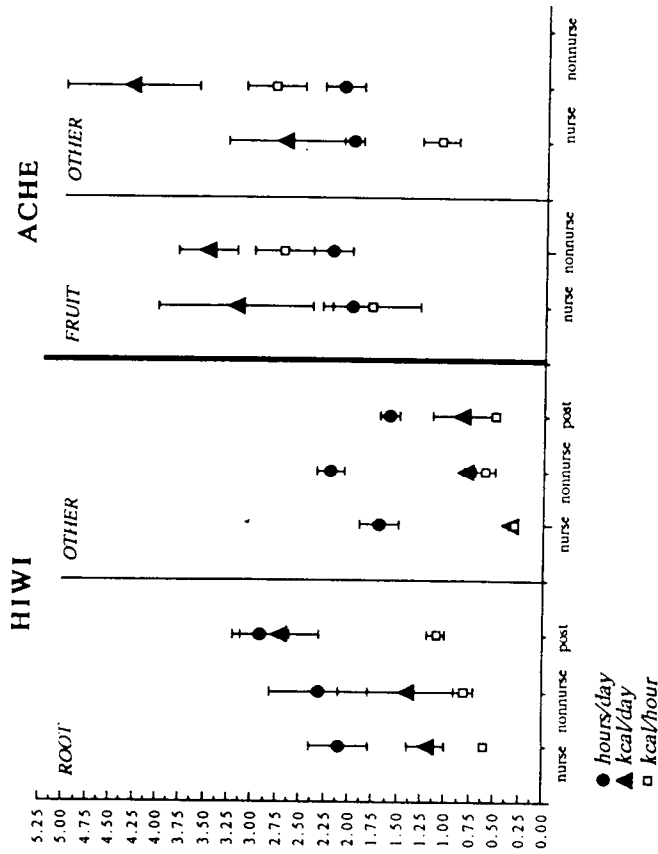


Figure 2. Mean hours spent foraging (Ache—palm starch gathering only), kilocalories acquired per hour (Ache—palm starch rates only), and kilocalories acquired per day by Hiwi and Ache women, stratified by group, season, and reproductive status.

energy on average with a range of 1.8 to 2.8 kcal/hr and 3.2 to 4.3 kcal/day (Figure 2). These descriptive data suggest that intercultural differences in time expenditures are considerably less marked than are caloric returns and total food acquired.

Differences between categories of women show similar trends in the two groups. In all seasons, nursing Hiwi and Ache women worked shorter hours and acquired fewer calories per day than nonnursing women. Moreover, the differences between nursing and nonnursing women in daily food acquisition appear to be less pronounced in the root and fruit seasons than in other seasons of the year.

In the Hiwi population we also measured differences between women of childbearing ages and postreproductive women. Figure 2 suggests that postreproductive women worked longer hours, achieved higher acquisition rates, and acquired more calories per day than nonnursing women in the root season but not in other seasons of the year.

Multiple regression analyses were used to examine these trends in Hiwi and Ache time allocation and caloric acquisition behaviors in order to examine the effect of each variable while controlling for the effects of other important factors. Because of the Poisson distribution of the outcome variables (foraging time, acquisition rates, and daily food acquisition; kurtosis values are >20), a $\log_{10}(x+1)$ transform enabled us to obtain normally distributed error terms with equal variance (Neter et al. 1985). We report regression coefficients in their original units (see below).

Because we are interested in modeling women's daily average foraging behavior as opposed to decisions regarding which days should be spent foraging, the monthly or trip daily means of the dependent variables were used as outcome variables in regression analyses. This procedure reduced our Hiwi sample on time spent foraging and daily caloric acquisition from 1820 to 119 woman-days and our sample size on acquisition rates from 719 to 112 woman-days (monthly means). The sample on Ache women was reduced from 461 to 56 woman-days (trip means) for the same reason. The data base for acquisition rates in the Hiwi sample is smaller than that for the other variables because return rates were calculated by dividing the total number of calories acquired on each day by the number of hours spent foraging on the same day. Since we did not collect data on both food acquisition and time spent foraging on all days, acquisition rates could only be estimated from smaller samples of Hiwi women.

The multiple regression models include the following independent variables: husband's mean daily caloric acquisition, reproductive status (postreproductive vs. reproductive age women; nonnursing vs. nursing), number of children/grandchildren, season of the year, and age of the subject. Interaction terms between reproductive status and children, reproductive status and season, and children and season were also added to the models. We ran analogous models in order to determine whether age of youngest child is a more important predictor of foraging behavior than reproductive status in our samples. In the first model we substituted nursing status with age of youngest child. In the second model, we simply added age of youngest child to the model. In both analyses, age of youngest child was an unimportant predictor in our models. Consequently, this variable was left out of subsequent analyses.

For the analyses of the Hiwi data we used two multiple regression models that require different coding schemes for the reproductive status independent variables (Table 3). The first model estimates the effects of the predictor variables when the behaviors of postreproductive women and those of women of reproductive age are compared. The second estimates the effects when postreproductive women are excluded from

Table 6. Multiple Regression Analyses of Foraging Time, Acquisition Rates, and Daily Food Acquisition among Ache Women of Reproductive Age

Factor	β	s.e.	β	s.e.	β	s.e.
HUSBAND'S FOOD ACQUISITION (per 1000 calories)	-0.5	0.3	*	*	-130	32
REPRODUCTIVE STATUS (nonnursing vs. nursing CHILDREN)	0.14	0.09	979	490	736	392
CHILDREN status by season	0.18	0.06	-879	484	1907	950
SEASON	-0.12	0.09	*	*	-493	490
AGE					1369	401

Full Model F-test = 3
 $p = .08$
 $R^2 = 0.22$
 $n = 40$

Full Model F-test = 4
 $p = .06$
 $R^2 = 0.24$
 $n = 26$

Full Model F-test = 5.6
 $p = .04$
 $R^2 = 0.41$
 $n = 54$

*Independent variable is not an important contributor to the model (see text)

Table 5. Multiple Regression Analyses of Foraging Time, Acquisition Rates, and Daily Food Acquisition among Hiwi Women of Reproductive Age Only

Factor	β	s.e.	β	s.e.	β	s.e.
HUSBAND'S FOOD ACQUISITION (per 1000 calories)	-0.8	0.7	-98	64	*	*
REPRODUCTIVE STATUS (nonnursing vs. nursing CHILDREN status by season)	1.6	1.3	360	320	281	134
CHILDREN status by season	1.2	1.15	273	161	216	168
SEASON	*	*	2110	338	2315	620
AGE	0.33	1.1	*	*	620	*

Full Model F-test = 8.7
 $p = .0004$
 $R^2 = 0.49$
 $n = 73$

Full Model F-test = 3.8
 $p = .0021$
 $R^2 = 0.33$
 $n = 71$

Full Model F-test = 3.7
 $p = .0004$
 $R^2 = 0.30$
 $n = 74$

*Independent variable is not an important contributor to the model (see text)

Husband's Food Acquisition

Interestingly, in both models the daily food acquisition of a woman's spouse is negatively related to female foraging effort in the Hiwi sample, and it is negatively related to foraging time and daily food acquisition in the Ache sample. Thus it appears that in both populations the wives of good providers spent less time foraging and obtained lower foraging return rates or daily food acquisition rates relative to the wives of poor providers.

Reproductive Status

Among the Hiwi, the effect of reproductive status on foraging behavior changes according to the season of the year (Table 4). A positive beta coefficient for the interaction term *postreproductive/reproductive by season* indicates that differences between postreproductive women and women of reproductive age in daily food acquisition are more pronounced in the root season than in other seasons of the year. Postreproductive women acquired more calories in the root season than did women of reproductive age whereas in other seasons of the year there is little difference between them (Figure 2).

Even though Hiwi postreproductive women acquired more calories per day than women of reproductive age, they *worked* shorter hours than did women of reproductive age (Table 4). A high point for postreproductive women relative to others in the root season (Figure 2) may reflect important confounding by factors that are not controlled for in the calculation of the means used in this figure (e.g., age).

Among Hiwi and Ache women of reproductive age, reproductive status is importantly associated with the three outcome variables. Non-nursing women worked *longer* hours than did nursing women in all seasons of the year. In addition, even though nonnursing women acquired more calories per hour and per day in general than nursing women, a negative beta coefficient for the interaction term *nonnursing/nursing by season* indicates that the differences in daily food acquisition (Hiwi and Ache) and rates (Hiwi only) between these categories of women are much less pronounced in the root and fruit seasons than in other seasons of the year (Tables 5 and 6).

Number of Children/grandchildren

In general, women increased *foraging time* as the number of children increased, but this trend is significant only among Hiwi and Ache women of reproductive age (Tables 5 and 6). We found a positive and

significant association between food acquisition variables and number of children in most samples (Tables 4–6). There are two interesting exceptions to these trends, however. First, in the Ache sample we found a negative interaction effect on daily food acquisition between number of dependents and season of the year. In consequence, on "fruit trips" the positive effect of number of dependents on daily food acquisition was less pronounced than it was on other trips. This finding suggests that when fruits were in season, Ache mothers with several dependents were less willing to increase foraging effort than they were during other seasons when they only acquired palm starch. Second, in the sample of Ache women palm starch acquisition rates only *decreased* as a function of the number of a woman's dependents. Ache mothers compensated for this decrease in rates by increasing time spent foraging.

Season

Time spent foraging did not vary significantly with season in the Hiwi sample; however, the analyses do show that in the root season all Hiwi women acquired significantly more calories per day (Tables 4 and 5 and Figure 2). Therefore, our data suggest that Hiwi women increase daily food acquisition in the root season through higher caloric return rates per hour as opposed to increases in foraging time.

Because only time allocation to the acquisition of palm starch is measured accurately for Ache women, we are unable to test for differences in total foraging time across seasons in this population. Our findings show that on fruit trips, Ache women spent less time in the pursuit of palm starch. In addition, women acquired more total calories per day than on trips when palm starch was the main carbohydrate staple.

Age

Among all Hiwi women, age is positively associated with time spent foraging, and it does not appear to affect acquisition rates and daily food acquisition. We did not find a similar effect in the Ache sample, perhaps because the age range over which significant variation in foraging behavior occurs is probably substantially longer (e.g., Hiwi women: 19–67 years) than the range we measured for the Ache (Ache women: 18–43 years).

Summary

A few consistent trends emerge from the data on Hiwi and Ache women. When all else was equal, the wives of good providers, post-reproductive women, nursing women, and women with fewer children

exhibited lower levels of foraging effort than their counterparts. Moreover, in both populations women acquired more total calories in seasons of the year when either fruits or roots were in season. Other behavioral patterns are less consistent across categories of women. Although Hiwi postreproductive women worked shorter hours than women of reproductive age, they acquired *more* food than women of reproductive age, particularly in the root season. In addition, even though Hiwi and Ache nursing women achieved lower foraging rates (or acquired fewer calories per day) than did nonnursing women, these differences became smaller in the root season and on fruit trips. Moreover, Ache women decreased, whereas Hiwi women increased their foraging rates as the number of children that they had increased. In addition, Ache mothers with several children to feed increased daily food acquisition efforts more on trips when only palm starch was gathered than on trips when fruits were the main carbohydrate staple.

DISCUSSION

Theoretical Assumptions

Descriptions of foraging behaviors among Ache and Hiwi women reveal some interesting insights into the trade-offs that individuals might face by spending time in food acquisition and in the care of infants and children. Our interpretation of the data is driven by several theoretical assumptions. First, we assume that the goal of behavior is to maximize inclusive fitness, and that individuals who behave optimally will adopt behavioral patterns that yield the highest fitness among available alternatives (Stephens and Krebs 1987). These alternatives are the different *combinations of goods* that are possible to obtain given acquisition rates associated with time spent foraging and in child care, and given how much time is available to women. We define the goods acquired through time spent foraging as calories of food, and those acquired through time spent in child care as "health insults that parents can avoid" (HIA).

HIA is a useful construct that can be operationalized in general terms as the number of health insults to children of a particular magnitude that will be experienced on average without adult supervision. These health insults include all *care-dependent* outcomes of morbidity and mortality in offspring (Harpending and Draper 1986). The operationalization of HIA, and the methods necessary to measure this variable accurately, is complex because health insults differ considerably in quality (e.g., psychological vs. physical health insults) and in magnitude (e.g., a fall vs. a car accident; see Levine 1977). However, this concept can be used to justify

why qualitative descriptions of differences in health hazards to children can be an informative distinction in descriptive studies of hunter-gatherers.

Our data suggest that there are important differences in the amount of food that women can acquire in Hiwi and Ache groups. Hiwi women acquired fewer total calories per day than Ache women. Even though in both groups women spent close to 2 hours foraging per day on average, Hiwi women acquired less than half (929 ± 60 calories per day, $n = 117$ monthly woman-days) the number of calories that Ache individuals acquired per day (2004 ± 190 , $n = 57$ trip woman-days).

This information is important because it suggests that, in general, time allocation decisions should probably be influenced by differences in the nutritional status of Hiwi and Ache women. Since Ache women in our sample acquired more calories per unit time, Ache women probably reach nutritional thresholds faster than do Hiwi women at any one point in time. The fact that Ache women are heavier than the Hiwi may further increase differences between the two groups in these thresholds. Consequently, all else being equal, the fitness value of additional food acquired should be higher for the Hiwi than for Ache women.

Our data also suggest that there may be important differences in the number of health insults to children that Hiwi and Ache women can avoid. Qualitative observations of the savanna and forest environments strongly suggest that the number of health insults that Ache women can avoid is substantially higher than among the Hiwi (see Study Populations). Several factors may result in fewer potential health hazards to children in the Hiwi environment than are present among the Ache. The Venezuelan savanna is a dry, safer environment with few insects, whereas the Paraguayan forest is a more dangerous environment with numerous biting insects and considerable dampness. In the savanna, women may have to be concerned about fewer hazards, and thus they may be more willing to set down their infants or allow toddlers to roam while they forage.

Other aspects of Hiwi socioecology may further reduce the number of and fitness benefits associated with avoidable health insults to children. Among the Hiwi, all women of reproductive age had at least one older female relative. These relatives frequently provided partial or complete child care while reproductive-age women foraged. In addition, unlike Ache men who forage an average of 7 hours a day, Hiwi men spend less than 3 hours per day foraging (Hurtado and Hill 1990). Hiwi fathers were coded as primary caretakers of children on 30% of women's foraging events. Finally, older Hiwi children spend almost 100% of the time with their parents and siblings (unpublished data), either in camp, foraging in the savanna, or along the river banks. These older siblings

frequently help their mothers with the care of younger siblings. In contrast to the Hiwi, Ache women did not have older female relatives that could help them; their husbands spent very little time with them during daylight hours; and their older children spent most of their time away from their families foraging with other children. Consequently, it is possible that during a 12-hour period, Ache women can avoid more physical health insults to children than Hiwi women, and that because of differences in hazardous exposures and allocare, the fitness benefits associated with child care are possibly higher for Ache than for Hiwi women.

Thus, Hiwi women are likely to gain more from increased foraging effort than is the case for Ache women. This conclusion is likely because Hiwi individuals are in worse nutritional status, they may have fewer health hazards to be concerned about, and they have many more helpers than do their Ache counterparts.

Empirical Contrasts and Inferences

In both populations we found that all women decreased time spent foraging with an increase in number of daily calories that their husbands acquired. This finding suggests that for both Hiwi and Ache women, regardless of reproductive status and number of children that they might have, the fitness benefits of foraging may decrease when a woman is married to a good provider. If the wives of good providers consume more food, they may reach some unspecified nutritional threshold faster than other women.

This result is interesting because it suggests that the nutritional status of the women and children in our samples were above some viable threshold. In general we should expect to find that when food provisioning by one parent is sufficient to raise the nutritional status of offspring above a viable threshold, decreases in foraging effort are probably beneficial to the second parent (Clutton-Brock 1991). Because Hiwi and Ache fathers in our samples acquired 80–90% of the calories consumed by their families, decreases in maternal foraging time and effort may be beneficial.

The data also suggest that nursing status has important effects on female foraging behaviors. In both groups, we find that nursing women are more likely to show reduced foraging time, acquisition rates, and mean daily caloric acquisition than do nonnursing women. Thus, Hiwi and Ache mothers appear to be more concerned about the safety of their infants than they are about increased energetic demands during lactation (but see below). Increased food acquisition among nursing women relative to other women might be expected when the extra food they

acquire significantly affects breast milk production, and when the abundance and quality of breast milk positively affects child survivorship. As has been found in other mammals, however, women sometimes avoid this potential benefit of increased food acquisition in favor of decreased foraging effort during lactation (e.g., Harrison 1983).

The data also suggest that nursing and nonnursing women among the Hiwi and the Ache generally face similar trade-offs. A full regression model that combines the Hiwi and Ache samples shows that interaction terms between group and nursing status do not importantly affect foraging time, acquisition rates, and daily food acquisition. This interesting result suggests that the number of health insults that mothers can avoid may be less affected by differences in ecology (e.g., dampness or cold) than we had expected.

Another interesting insight into the trade-offs that Hiwi and Ache women might face is implied by the mediating effect that ecological factors have on the relationship between nursing status and foraging effort. Our data suggest that when women can acquire more calories per hour (i.e., when fruits and roots are in season), nursing women tend to increase work to the levels observed for nonnursing women. This finding was surprising in the Hiwi sample since harvesting technologies in the root season involve setting infants down on the bare ground. Thus we would expect health insults to children to increase significantly for Hiwi mothers who worked hard in the root season. Possibly, helpers (mainly fathers and older children) buffered potential hazards to infants, and Hiwi mothers found other ways to accommodate child care with foraging activities (see below). It is also important to remember that Hiwi women and children are poorly nourished, and they experience substantial carbohydrate stress during most of the year (Hurtado and Hill 1990). If these factors positively increase the fitness value of food acquisition in the root season over that characteristic of other times of the year, then increases in foraging effort among Hiwi nursing mothers may be an adaptive response to seasonal food stress.

Further analyses of the age of youngest child, women's acquisition rates, and time spent foraging provide some insights into the behavioral adjustments made by Hiwi nursing mothers in the root season. First, a strong positive relationship between age of child and caloric return rates at root patches (Figure 3) supports the premise that nursing mothers sacrifice food energy in favor of child care when nursing children are present at the foraging site. Second, among the Hiwi, nursing women stay longer at the root patch when they take their infants along than if they leave them behind with a caretaker, but nonnursing women quit earlier when their youngest child accompanies them to the foraging site (Table 7). Hiwi women in our sample were thus able to increase food

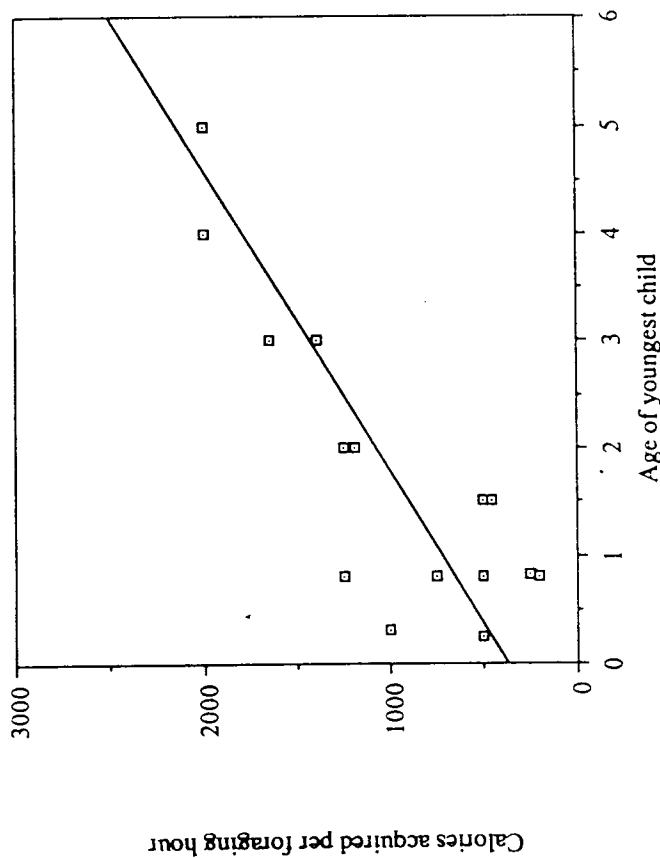


Figure 3. Association between age of youngest child present at the root patch and calories acquired per hour spent foraging among Hiwi nursing women.

acquisition levels by increasing time spent at the root patch when infants went along, and by increasing rates when infants were left behind. This finding makes sense when we consider how each child is cared for. A nursing woman is likely to be concerned about breast-feeding the infant regularly and cannot be separated from her infant for long periods. A nonnursing woman may be concerned about her child becoming hungry and about having no food to give him or her at the root patch (roots require considerable food processing before they are edible).

The mediating effect of ecology on the relationship between nursing status and foraging effort in the Ache population seems more straightforward. When fruits are in season, potential hazards to children during foraging bouts are probably substantially lower than in other seasons of the year. Women not only hold their infants while they forage, but they do so in areas of the forest that are more clear of underbrush than areas where palm trees are generally exploited. Consequently, it is not surprising that nursing mothers take advantage of this opportunity to acquire food at a level that is closer to those of unencumbered women than at other times of the year when food (mainly palm starch) is exploited at more hazardous foraging sites.

Table 7. Comparison of the Mean Number of Hours Spent at the Root Patch among Women of Reproductive Age Stratified According to the Presence of Youngest Child at the Root Patch and Mother's Reproductive Status

	Nursing Women	Nonnursing Women
With youngest child*	6.4 ± 0.5 n = 17	3.9 ± 1.2 n = 4
Without youngest child	4.9 ± 1.1 n = 20	5.6 ± 2.2 n = 12
	p (two-tailed) = 0.0324 paired t-test	
	p (two-tailed) = 0.1029 paired t-test	

*between birth and 5 years of age

The effect of number of children on female foraging behavior provides some evidence for possible differences in the trade-offs that Hiwi and Ache individuals face. These differences are consistent with the variation in HIA across these two groups of foragers. Even though Hiwi and Ache women increased foraging time, acquisition rates, and daily food acquisition as their number of children increased, *Ache women decreased foraging acquisition rates as the number of their children increased*. A decrease in foraging rate may occur because Ache women intermittently monitor small children during actual foraging events, and these interruptions in turn account for a decrease in acquisition rates. Interestingly, women compensated for this sacrifice in efficiency by working longer hours. Again, we suspect that Ache women might do so because they were able to avoid more health insults to small children per unit time at the foraging patch than Hiwi women.

Ecological factors also appear to mediate the relationship between number of children and daily food acquisition among Ache women. In the fruit season, Ache mothers tend to increase daily food acquisition less steeply per child than on trips when only palm starch was gathered. This finding is interesting in light of the fact that nursing mothers increased foraging effort vis-à-vis their nonnursing counterparts in the fruit season. Consequently, when fruits were in season, women seized the opportunity to eat more when they were nursing, but not to acquire more food for their dependent young. A possible explanation for this finding is that Ache children fed themselves competently at fruit patches (cf. Blurton-Jones et al. 1987). Thus, on fruit trips children were less dependent on their mothers for vegetable foods than on trips when palm starch was the main carbohydrate staple. Palm starch was only acquired by adults, and only small amounts were consumed on the spot. Consequently, the benefits to maternal increases in food acquisition

when fruits were in season were probably lower than they were in other times of the year when children were not able to feed themselves at the foraging patch.

Unlike among the Ache, Hiwi children were relatively incompetent tuber and fruit gatherers because roots are hard to dig out, and fruit trees are found in clumps at long distances from the central camp (Hurtado and Hill 1990). Therefore, Hiwi mothers probably gain important nutritional benefits by increasing foraging effort at the same rate per additional dependent child in all seasons of the year.

The data on seasonal differences in foraging effort between women of reproductive and postreproductive age provide further insights into the trade-offs that women face between spending time in food acquisition and in child care across the life cycle. When reproduction is no longer possible, the costs of foraging are relatively low because energy reserves are no longer necessary to sustain viable pregnancies. In the root season, grandmothers are the hardest-working individuals in Hiwi society. Although increases in foraging time did not occur, postreproductive women acquired more calories per day than younger women, possibly through an increase in foraging rates. Grandmothers specialized in food acquisition during this season and did not care for their daughters' children throughout the sampling period (0 out of 52 root foraging events sampled). In contrast, postreproductive women on average acquired as little food as did nursing women in other seasons of the year, and they took care of grandchildren while their daughters foraged 40% of the time (29 out of 73 events sampled).

Perhaps grandmothers work hardest in the root season in order to buffer the effects of the long periods of carbohydrates stress that their offspring experience. Hiwi men and women lost weight over several months after the root season peak (Hurtado and Hill 1990). In combination with low overall gathering return rates in most seasons of the year, this stress probably increases the value of grandmaternal foraging time over child care substantially in the root season (see also Hawkes et al. 1989).

A positive correlation between age and foraging time among women of reproductive age in the Hiwi sample indicates that a decrease in the reproductive value of women may play a role in women's economic strategies. With the loss of reproductive value, women may be selected to increase their investment in offspring (Curio 1988; Williams 1966). Our findings suggest that when women are matched for various other covariates of foraging behavior, older women forage longer hours than younger women. Although evolutionary theory predicts that greater investment per offspring should occur with age and decreasing reproductive value, it does not tell us in what form. Apparently, in the root

season, foraging effort takes precedence over time spent in other activities, including child care.

CONCLUSIONS

Taken together, these findings have important implications for understanding the selective pressures operating on the division of labor by sex and grandmaternal investment in the Hiwi and Ache populations. The variation in female foraging effort, and its implications for the amount of food that women can provide for themselves and their offspring across the life cycle, suggests that selection pressures on female choice for good providers should be considerable under circumstances such as those experienced by Hiwi and Ache women. Hiwi and Ache women can expect to spend long periods of their adult lives lactating, and these periods of time are consistently associated with a decrease in foraging effort. In the Ache population, meeting the competing demands of providing effective protection from the environment and adequate nutrition for children is very difficult, and child care usually takes priority. Among the Hiwi, even though these competing demands appear easier to meet simultaneously, women still depend on their mothers and husbands for food provisioning and child care. In spite of extensive paternal food provisioning among the Ache and the Hiwi, and grandmaternal investments among the Hiwi, female fertility is low compared to rates experienced by other natural fertility populations (Hill and Hurtado 1992). Hence, female fitness would probably be considerably lower without male food provisioning and possibly grandmaternal investment (Hill and Hurtado 1991).

The findings also have important methodological implications. First, the effect of reproductive status, number of children, and seasonality on female foraging behavior among Hiwi and Ache women suggests that aggregate analyses may be biased and only partially informative estimates of sex differences in foraging behaviors across groups of hunter-gatherers. In a previous study on Hiwi foragers we reported that women acquire about half of all the calories that are consumed by the group, based on data gathered during part of the root season (Hurtado and Hill 1986). This apparent equality was due primarily to an increase in the acquisition rates of postreproductive women during this season, and not to increases in food acquired by women of childbearing age. This characterization of sex differences in food acquisition therefore obscured the fact that during most of the year Hiwi women acquire less than 20% of the total calories that are consumed, and that postreproductive women are primarily accountable for an apparent equality in the foraging efforts

of the sexes during the root season. These issues need to be explored for other groups as well, where descriptions of entire economies are sometimes based on seasonally biased samples of individuals whose reproductive and dependency statuses are not specified (e.g., Lee 1979). A more accurate appreciation of the cross-cultural variation in the division of labor by sex in foragers (Ember 1978) will be possible when investigators systematically report seasonally stratified and reproductive status-specific statistics in future studies.

Lastly, this study has important implications for current explanations of sex differences in subsistence strategies. The pervasive notion that compatibility between child care and female economic behavior may explain the division of labor by sex obscures what appears to be a more complex causality of female economic choice (see Hurtado et al. 1992). Women are probably less "constrained" by children *per se* than by the socioecological factors that affect the amount of goods (e.g., food and IHA), and the associated fitness benefits, that women can obtain from spending time in subsistence work and child care. In order to test this general proposition, we will need to develop and test optimization models of female economic choice with data on large samples of women and children over long periods of time. The most challenging and difficult aspect of this research will be to measure the number of health insults to children that parents can avoid, or care-dependent child morbidity and mortality (see Hurtado et al. 1992). Ultimately we hope that these theoretical and methodological efforts will help us specify how competing reproductive and economic roles in human females contribute to sex differences in parental investment.

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